The Potential of Various Types of Thermal Effects on Chesapeake Bay

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ABSTRACT

Shifts in natural temperatures have physical, chemical, and biological effects upon the receiving body of water. They may affect the viscosity of water and thus the ability of plankton to float. They may affect the circulation pattern of water and hence the current pattern in the Bay. Raising or lowering the temperatures decreases or increases the oxygen-carrying capacity of the water. Shifts in temperature also have considerable effect upon the organisms living in the Chesapeake Bay—for example, their physiological activities. Shifting the natural rhythms of temperature may affect the reproduction of organisms. The effects of sudden changes of temperature are closely related to time of exposure. Organisms can withstand higher shifts in temperature for short exposures than if the temperatures are of longer duration. Much more research needs to be done as to the beneficial effects of temperature. In conclusion, important biological, chemical and physical conditions for power plant siting are set forth.

The Chesapeake Bay is one of the largest estuaries in the world. It is approximately 180 miles long and has a mean width of about 15 miles (Wolman, 1968). However, it is a relatively shallow estuary, as the mean depth of the Bay proper is 25-30 ft. Because it is so large and shallow, the waters are turbulent and during most of the year well mixed, although stratification does occur during the summer months. The shallow water margins of the Bay where most of the aquatic life lives is subject to strong wave action during most of the year and also to the deposition of sediments due to bank erosion.

The Chesapeake estuary is a drowned portion of the Susquehanna River system and is estimated to be about 10,000 years old. The greatest inflow of water is from the Susquehanna, which has a mean annual flow of 40,000 cfs. The Potomac, Rappahannock, and James Rivers also have significant flows of fresh water, but it is the flow of the Susquehanna which has the greatest influence on water quality, particularly on the west side of the Bay.

The increase in population in the drainage area of the watershed and the Bay proper has brought about a fairly high amount of pollution in certain areas. I refer particularly to suspended solids and nutrients.

The suspended solids are brought in by various tributaries and by the erosion and deposition of sediments forming the coastline of the Bay. Prior to the clearing of the portions of the watershed forests for agriculture, the sediment contribution to the system was probably in the order of 100 tons/mi^2/year. However, with the clearing of the land for agriculture and urbanization these values rose to 400 to 800 tons/mi^2/year. The Potomac and the Patuxent, although having much less flow than the Susquehanna, are the largest contributors of sediments. The dams on the Susquehanna greatly reduce the suspended solids contribution of this river.

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With the increase in population has come increases in nutrients entering the basin. This is particularly evident in Baltimore Harbor and in many of the small embayments where towns and industrial development have taken place. Indeed, in some of these areas pollution is heavy, and bluegreen algal blooms in the summer months are extensive. However, the contribution of nutrients to the Bay are negligible because of the size and degree of mixing of the Bay water. The Susquehanna River contributes a large portion of the nutrients in the form of NO_3 to the Bay, particularly during the spring of the year when the concentration in the flow is 80-105 μg atm/1 and concentrations in the upper Bay may reach 45 μg atm/1.

The importance in considering these 2 types of pollution in relation to temperature is that the deposition of sediments together with increased nutrients and small increases in temperature often bring about increased growth in benthic algae and rooted aquatics, which may or may not be beneficial depending on the species that develop. If they are effective food sources, productivity of fish and other organisms increase, whereas if they are species of little value as food and predator pressure is low, nuisance growths may develop.

Temperature, unlike some pollutants such as some heavy metals and pesticides, is part of the natural environment. All organisms have a range of temperature in which they live and a smaller range in which optimum living and growth conditions occur. This range of tolerance and optimum activity varies with the species and with the life stage of the organisms. Typically, as shown by diatom experiments which I have conducted, if one raises temperatures a few degrees toward the optimum, the number of species in the community and the sizes of their populations increase, and as a result diversity increases. The biomass also may increase. For example, small increases from 2.8 to 10°C and from 5.7 to 10.4°C. Since diatoms are a nutritive food source, the productivity of the whole system may be increased. However, if one moves away from the optimum range, either up or down, species reduction and/or reduction in sizes of populations of most species and of biomass occurs. It is true that a few species which are tolerant to the new condition may develop large populations which result in lower diversity. Increases in temperature often bring about changes in the species composing communities. For example (Patrick *et al.*, 1969), if one maintains the temperature above 33°C in White Clay Creek in Pennsylvania, one can bring about a change from a diatom-dominated to a blue-green dominated flora at any season of the year. Since blue-greens are not as desirable a food source, predator pressure goes down and the efficiency of energy transfer in the system and the production of fish is reduced.

Temperature affects the chemical and physical characteristics of the aquatic environment as well as the organisms themselves. The viscosity of water is greatly affected by temperature, and plankton which can float in cold or cool water will sink in warm water to that depth at which the viscosity of the water will support them. Likewise, suspended solids will sink more quickly in warm than in cold water. Typically the deeper waters of the Chesapeake Bay are cooler than the surface waters and lower in oxygen in the summer. The introduction of warm water into these cooler layers might locally produce considerable change in the circulation pattern of water with accompanying alteration in the oxygen and salinity and perhaps nutrient patterns natural to the bay. Most chemicals are more soluble in warm water. The oxygen-carrying capacity of water is reduced with increases of temperature, and as a result fish and other gill-breathing organisms have to dilate their gills much more rapidly in warm than in cold water to obtain enough oxygen for life. Indeed the respiration rate of many organisms increases with increases in temperature, but in some organisms after acclimation the respiration rate returns to its former level.

Examples of alteration in the natural functioning of other physiological processes are changes in the lipid content in the brain and spinal cord of fish (*Aequidens portalegrensis*); and in acetyl cholinesterase in bluegill (*Lepomis macrochirus*) brains, both of which have been correlated with changes in temperature (Schneider, 1969; Hogan, 1970). Acclimation to low temperatures for 8 days produced in crayfish an increase in hepatopancreas weight, lipid unsaturated lipids, ribonucleic acid, and free amino acid. Suppression of defecation rates in the tubificid worms (*Peloscolex multisetosus*) has been shown to occur when the temperature is raised from 14 to 18°C.

Many organisms cease to feed, or feed at a slower rate at low temperatures. Examples are the oyster drill (*Urosalpinx cinerea*) and the flatworm (*Stylochus ellipticus*), which feed at a much slower rate at 10°C or less (Manzi, 1969, 1970; Landers and Rhodes, 1970).

Temperature rhythms are important in the natural functioning of many organisms. For example, in Maryland the reproduction of bass seems to be triggered by the temperature of the water increasing from the low sixties (°F) to the high sixties in the Spring of the year. In the Missouri River the spawning of the freshwater drum (*Aplodinotus grunniens*) occurred when the river water reached 18°C. Oysters in the Chesapeake spawn when the temperature of the water passes from the high sixties to the low seventies in the Spring. The emergence of insects in the Spring may be advanced by raising the temperature 10°F (experiments at Stroud Water Research Center).

Sudden changes of temperature may have a profound effect on aquatic life. The sudden increase in temperature of water may bring about the release of gas bubbles in the blood of fish (embolism) which causes death. This phenomenon may occur when the flow of cold water from a dam is suddenly stopped and the pool of water at the base of the dam warms quickly. Sudden rise in temperature such as occurs when organisms are entrained through a power plant may have adverse effects. The severity of the effect seems to be determined by the degree of temperature to which organisms are exposed and the length of time they are exposed to the higher temperatures. Many organisms can withstand for a very short period of time (a few minutes) temperatures which would be lethal under longer exposures. The length of exposure to high temperature seems to be very important in determining the severity of the effect. The effect on entrained organisms in coolant water seems to be related to the size and characteristics of the species, the degree to which the temperature rises, and the time of exposure.

In general, acclimation of organisms to a new temperature regime is a slow process and if carried out too quickly will result in deleterious effects and even death. Therefore, very short sudden rises of temperature and subsequent quick return to ambient not involving acclimation has less deleterious effect than sudden rises of temperature with prolonged exposure to the higher temperature, which necessitates acclimation, particularly if the organism has not been correctly acclimated.

Abnormal temperature regimes have also been shown to affect the susceptibility of organisms to disease and predation. For example, oysters seem to be more susceptible to *Dermocystidium* when exposed to temperatures of 75°F and over lor long periods of time. Parasitized snails (McDaniel, 1969) are less tolerant to high temperature than non-parasitized snails. Furthermore, predator pressure from oyster drills and flatworms (cited above) seem to be less at temperatures of 10°C or less.

From this discussion it is evident that all species of organisms have a range of temperature tolerance and within this range a shorter range of optimum temperature. This range varies from species to species and between races of the same species. It also may be different for different stages in the life history of an organism. There is evidence that moderate raising or lowering of temperatures toward the optimum is favorable for species.

The precise temperature, high or low, which is deleterious or kills a species is closely related to the time of exposure. Shifts in natural temperature regimes may indirectly affect organisms in various ways. It may increase the susceptibility of the species to disease and predator pressure, it may change other chemical and physical characteristics of the environment in which the aquatic community lives and thus indirectly alter competition and predator pressure.

Most of the experimentation to date has been directed toward deleterious effects of temperature. However, there are a number of experiments now in progress directed toward showing beneficial uses of warm water in oyster, shrimp, and fish culture; in treatment of sewage; in treatment of water for industrial use; and in beneficial effects in irrigation. Many of these show considerable promise for the use of this low-heat resource.

To date the impact of altered temperature regimes in the Chesapeake Bay are local. Although there are many plants on the tributaries, there are very few fossil fuel plants (2 in Baltimore Harbor and 4 close to the mouth of the Bay) located on the Bay proper, and 1 nuclear plant in the process of construction. By the year 2000 it is expected that 10 plants about the size of the Calvert Cliffs plant will be erected. It is important that the various States bounded by the Bay develop uniform plans for the development of all industries and population centers on the Bay so that the least impact which might be deleterious to its natural functioning will occur. It is as important to plan for the preservation of natural areas as for development.

In developing plans for siting power plants and other industries with thermal discharges, one must consider biological, chemical, and physical aspects of the Bay. Some of the more important biological considerations are:

1. What are the kinds of aquatic life living in the vicinity of the proposed plant site and what are the temperature optimums and tolerance for these organisms?

2. Are there nursery and spawning areas?

3. Is the plant site in the area of an important migratory path of fish and crabs?

4. Do fish form large schools in deep water in the winter time in the vicinity of the site?

5. Do large populations of crabs hibernate in the bottom sediments in the area?

6. What are the characteristics of the plankton in the area and does the plankton at certain seasons of the year contain the young of many species?

Some of the more important chemical aspects to consider are:

1. What is the nutrient level of the water and are these nutrients biodegradable?

2. What are the oxygen and salinity regimes of the water, and will the intake and heating of water at that particular site produce more than a local effect on these regimes which might be deleterious to aquatic life?

Some of the physical considerations are:

1. Is the flow sufficient so that the volume of water passing through the plant will be only a small portion of the total flow?

2. How will the introduction of the projected volume of coolant water affect the current pattern of water in the area?

3. What will be the isotherms of increased temperature produced by plant operation, and how much of the bay will be affected by a significant rise of temperature?

4. Will the removal of water from the deep layers be sufficient to alter the general pattern of stratification, particularly in the summer?

5. Will reverse flow cause accumulation of heated water in marsh areas which are often important breeding and spawning grounds? At some seasons of the year and under some conditions this effect might be beneficial, and others detrimental.

The design ot the plant may also greatly minimize thermal effects—for example, the location of the discharge away from the shallow water areas where most organisms live and reproduce; the use of low intake speeds to minimize the entrainment of fish and macro-invertebrates; the placement of the intakes so that cool water with low plankton content is taken in; the minimization of time of exposure and degree of heat to which organisms in entrained water are exposed; the use of substances similar to Amertap for slime removal; and the use of chlorine in such a way that there is no or very little free chlorine residual entering the receiving body of water.

I have for the most part mentioned some of the more important ways to minimize deleterious effects of thermal changes in Chesapeake Bay. I believe that much more emphasis than in the past must be placed in the future in optimizing the use of warm water, which should have an ultimate beneficial effect on the Bay.

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Heavy Metals—an Inventory of Existing Conditions[1]

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ABSTRACT

In this paper we report on studies undertaken to: (1) establish mercury levels in biota and sediments from the lower portion of Chesapeake Bay; (2) describe the pattern of metal distribution in oysters from 3 Virginia estuaries; and (3) determine if estuarine sediments can be used to detect the effects of man's activities on the environment. To date, mercury analyses of biota from the Bay area have shown no levels in excess of FDA guidelines, nor have they indicated any influence of man's activities in the areas studies. Oysters have been shown to vary naturally in their body burdens of the heavy metals—copper, cadmium, and zinc—and techniques are suggested whereby unnatural heavy metal inputs can be identified. Sediments from an industrialized river system have been shown to reflect the inputs from human activities.

An attempt is made in this report to inventory the status of knowledge on certain metallic elements in the lower portion of Chesapeake Bay. Some of the data presented have been published or submitted for publication elsewhere, and in all cases the sources of information are identified. Much can be learned from what we have called the inventory approach, as one in an attempt to explain what has been observed is usually forced to consider many variables which *a priori* were not thought to be significant. During this process, interpretations are frequently made which suggest avenues for future research. Initially, however, the objective of any inventory is to establish the existing conditions—in this case, the distribution of certain heavy metals in sediments and biota from the Bay region. Studies of the

[1] VIMS Contribution No. 435.

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